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STRATEGIC RAW MATERIALS IN EAST AND WEST.

9. Steel Alloying Metals.

d. Molybdenum.

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CONTENTS.

Explanation of Symbols:

... = Data not available.

\- = Magnitude nil or negligible.

1. Properties and uses.

1.1. Properties.

Molybdenum is a soft, supple silver white metal, looking rather like platinum. It is one of the rarest elements in the crust of the earth and is comparable to antimon in this respect. Its specific gravity is 10,2, its melting point some 2620 degs. Its electric conductivity is less than 1/3 that of copper. Its most characteristic qualities, moderated, however, at high temperatures, are strength, toughness and resistance to repeated shocks; but molybdenum is easily oxidized. On heating it may be stretched, hammered, folded, weaved, corroded and engraved. Molybdenum is easily weldable to nickel but only with difficulty to itself.

1.2. Uses.

Fifty years ago nearly the entire world production went into the chemical industry. Since then numberless other applications have been found. The rising importance of molybdenum is best illustrated by the fact that consumption was increased tenfold from 1930 to 1940.

In peacetime about 70 per cent. of total molybdenum production is used in alloys with steel and iron. In wartime this percentage is increased to about 90 per cent. There are two molybdenum steel types: one a low-grade containing less than 1 per cent. and a high-grade containing more than 1 per cent. of molybdenum. Low-grade molybdenum steel contains between 1,15 and 0,4 per cent. of molybdenum and is finding application in an increasing degree in airplanes, automobile and railway engine parts, machine tools, excavation and pumping appliances, agricultural machines, oil drilling equipment and petroleum refineries. Molybdenum steel is used in certain types of stainless steel and in permanent magnets. Chromium steel with molybdenum is used in the building industry and in mining equipment in which resistance to corrosion is required.

In the machine tool industry molybdenum is used as a substitute for nickel, chromium and manganese and side by side with tungsten. In the latter case both price and carriage conditions favour the use of molybdenum. High-speed tool steel has a molybdenum content of up to 9 per cent. which is thus to replace part of the usual tungsten content.

Metallic molybdenum is used in a number of types of electric equipment, such as glow lamps and radio valves. Electric contact points made by molybdenum have a life fifty times as long as similar ones made of silver.

Molybdenum is used increasingly in the chemical industry for dyes, ink for colouring leather, rubber and wool, and for enamels.

Entirely new is the use of MoS_2 as a dry lubricator in motors together with the traditional liquid lubricators. It reduces the wear substantially, one reason for this being the circumstance that it prevents direct friction even under high pressure or at high or low working temperatures.

[redacted]

Tungsten, nickel and platinum may in certain cases replace molybdenum.

Table 1 shows the distribution of molybdenum consumption among the various fields of application in the United States in 1952.

Table 1.

Distribution of Molybdenum Consumption [redacted] in 1952.

	per cent.
Steel	63,7
Grey iron and malleable castings	27,8
Metallic molybdenum	1,9
Dyes and paints	1,8
Welding electrodes	1,4
Catalysts	0,8
Lubricators	0,3
Others	2,3
Total	100,0

2. The Production Process.

Molybdenum is not found in its pure state. It is recovered from two minerals, the main part from molybdenite, MoS_2, and small quantities from powellite, $Ca(MoW)O_4$. In some steel works molybdenum is recovered from tungsten concentrate.

The ore from which molybdenum is extracted does not, as a rule, contain more than 1 per cent. of molybdenite. The crude ore passes through a concentration process. It is first crushed and then further concentrated by flotation. The molybdenite content of the ore has now reached a level of 90 per cent. The concentrate is roasted to make sulphur compound with oxygen. Then a reduction takes place through the addition of thermite. A further reduction is effected by evaporation and condensation.

3. Ore Deposits.

[redacted]

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3. In the Soviet Bloc.

The USSR. Information on the molybdenum situation in the USSR is scarce. However, it is certain that molybdenum is one of the most critical minerals in the USSR and a definite deficit commodity although the supply situation has improved in recent years. The output of the various mines is small and the reserves insignificant, probably far below the 190.000 tons of molybdenum content required to meet the demand until 1970.

The Soviet molybdenum deposits may be divided into four groups:

1. One group distinguished by a high molybdenum content, but the separate deposits are small.
2. Another not unlike the first but here molybdenum is found together with tungsten which predominates. These deposits are of little importance as a molybdenum source.
3. Tyrny-Auz is a typical example of the third group. This group is granite formations mixed with limestone, clay and sand. The ore is solid and contains schelite and molybdenite. The molybdenum content is only 0,2-0,3 per cent.
4. The fourth group consists of molybdenum-enriched ore veins, often found in copper ore, as e.g. at Kounradskiy. These deposits usually have a very small molybdenum content.

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The deposits are:

Tyrny-Auz in North Caucasus is the largest molybdenum deposit in the USSR. In 194o, 9o per cent. of the country's known reserves were located here. The ore reserves are to-day estimated at about 1oo mn. tons. The quantities mined until now amount to between 1o and 15 mn. tons a day and up to 1,5-1,6 mn. tons annually. The ore mined has an average content of o,o75 per cent. of molybdenum, o,22-o,25 per cent. of WO_3 and o,o2 per cent. of copper.

The mining is carried out partially in open-cast mines. The open-cast mine fartherst down is situated at an altitude of 9162 feet above sea level. The major part of the output comes from underground mines however, the lowest mining altitude of which is 7825 feet. Mining is carried out by means of blasts of 15o tons of amonite per volley. The blasts take place once a month. About 5-6oo grammes of explosive are used per ton of ore. 1ooo men in all work in the mines.

Attached to the deposit is a concentration plant which produces molybdenum and tungsten concentrate. The deposit was discovered in 1934. In the following year a prospecting enterprise was commenced. Work on the concentration plant was started in 1937 and production was taken up in 194o. The entire works was destroyed in the war but was rebuilt and put into operation again in 1945. 3.1oo are employed here.

Productivity in the mines would seem to be low. In other countries the normal output is 1o-15 tons per capita, in 8 hours' shifts, which means 26oo-39oo tons annually per capita with 26o shifts annually. A labour force of 4oo-6oo men should, thus, be adequate to ensure an output of 1.5 mn. tons per annum, whilst the abovementioned mines employ, as was said, 1ooo men. The technical equipment of the mines is rather old-fashioned, some mechanization has, however, been carried out. The repair costs seemed high.

The Kounradskiy Copper Mines contain considerable quantities of molybdenum, estimated, on the basis of its relation to copper, at 16.7oo tons.

Pirdaudan, in the Transcaucasus, 3o kilometres west of Zangezur, has substantial molybdenum reserves, but the per cent. content is not known. If, however, it is the same as at Kounrad the reserves amount to 12.ooo tons.

At Gorodok in the Buryat-Mongolian district on the Dzhida river are located tungsten and molybdenum mines. The same is the case in the Chita region. Molybdenum is also mined at Bukaka and Kolanguy east of Olovyannaya.

In the Karaganda district in Central Kazakhstan tungsten and molybdenum mines are situated at Akchatau north of Lake Balkash. 58 per cent. of Soviet molybdenum is said to come from Kazakhstan.

North of Naryn in the Fergana valley in the Kirgiz SSR wolframite and molybdenum is mined in such places, among others, as Kum-Bel and Kashka-Su.

Monchegorsk. Molybdenum is recovered together with nickel, copper, titanium, vanadium and zirkonium in the Monche tundra west of Lake Imandra in the Kola peninsula.

Dzhezkazgan in Kazakh SSR. The copper deposits here also contain molybdenum.

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[redacted] experts have estimated the Soviet molybdenum reserves at c. 45.000 tons of which 17.000 tons are said to originate from Kounrad and 25.000 tons from two inactive copper deposits. [redacted] it is possible [redacted] to establish the fact that the Soviet reserves are a good deal larger, perhaps somewhere between 80 and 100.000 tons. The Tyrny-Auz reserves alone represent between 45 and 75.000 tons. Further, as has often been stated in official Soviet quarters, significant discoveries have been made in recent years. Thus the area beyond Lake Baikal is said to be rich in molybdenum as well as other minerals.

The Satellite Countries. Molybdenum deposits of unknown size are located in North Korea and China. From 1933 to 1936 the North Korean average molybdenum production amounted to 98 tons per annum. During the war Japan started a molybdenum production in Manchuria, which has probably been carried on under the Communist rule. This assumption is also supported by statements made by the Russian representative at the 19th International congress of geologists, at which he affirmed that Russian geologists have discovered several molybdenum deposits in Manchuria and that production was considerable. To-day China is probably the second greatest molybdenum producer in the Soviet Bloc.

Czechoslovakia. There is molybdenite at Krupka in northern Bohemia. The deposit is probably only a small one. Only ore containing at least 0.1 per cent. of molybdenite is mined.

4. Production.

[redacted]

4.2. The Soviet Bloc.

Before World War II the Soviet molybdenum output was but slight. D.B. Shimkin, in his "Minerals, a Key to World Power", estimates that the 1937 production hardly exceeded 2oo tons. During the war a considerable expansion took place. Thus, the recovery of molybdenum from the Vortochnyi Kounradskiy deposit near Lake Balkash was begun, together with a by-production of molybdenum concentrate from the Kounrad copper ore. Further, small quantities were recovered from minor deposits in Kazakh SSR, the Transcaucasus and Transbaikalia. The total of these outputs represented a trebling of production between 194o and

[redacted]

[redacted]

1943 despite the fact that the USSR lost its largest molybdenum deposit Tyrny-Auz in the Caucasus during this period.

It is not easy to say how large the Soviet molybdenum production is to-day. Little information is avaiable and the western estimates vary a good deal.

From information available it is possible at least to attempt an estimate of the lower production limit:

1. Soviet officials have often stated that 58 per cent. of the Soviet molybdenum output originates in Kazakhstan.
2. Annual production at Tyrny-Auz in North Caucasus and Pirdaudan in Transcaucasus is 1.o25 and 1.2oo tons respectively or a total of 1.175 tons which is at most 42 per cent. of total Soviet production.
3. Thus Russia's molybdenum production is at least 2.8oo tons a year and probably more. In the first place, molybdenum is also produced in the area round Lake Baikal and in several other places outside Kazahk SSR, and secondly the production figure for Pirdaudan is not of recent date and so there is reason to believe that it is larger to-day.

[redacted] Soviet molybdenum production is to-day more than 3.ooo tons a year. This figure is in conformity with other western estimates which range from 3.ooo to 6.ooo tons.

x) Cordero mentions the following refineries which prepare molybdeniferous ore:

<u>The Nizkny-Baksan</u> plant is connected with the Tyrny-Auz deposit in North Caucasus by a cable railway 5 kilometres long. This plant is perhaps the largest copper refineri in the USSR.

<u>The Balkash Combine</u> is one of the largest copper refineries in the USSR. The ore comes from the near-by Vortochnyi Kounrad deposit. The combine is situated near the coast of the Bertys bay in the Balkash lake.

<u>The Kadzharan (Kafan) copper-molybdenum combine.</u> This combine is in the same area as the Zangezur works and its production seems to be based on Pirdaudan ore.

<u>Gorodok.</u> There is a refinery here connected with the mines.

Outside the USSR there is molybdenum production in <u>North Korea</u> and <u>China (Manchuria)</u>. In the years 1933-1936 the North Korean output amounted to an average of 98 tons of concentrate annually. Production in Manchuria started during the war and reached 516 tons in 1944. In the same year Japan produced 416 tons of ferromolybdenum in North Korea. This production was probably based on ore from both countries. To-day at least the Chinese production is of great importance for the molybdenum supplies to the Soviet Bloc. Various western estimates mention a Chinese molybdenum production of c. 1.6oo tons.

Outside the Soviet Bloc proper there is Yugoslavia but this country is economically and politically under a certain Russian influence and part of its output, perhaps all of it, accrues to the Communist world.

x) H.G. Cordero: World's Non-Ferrous Smelters and Refineries, 1954.

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The size of Yugoslavia's deposits is not known, but already before the war the country had a quite considerable production (thus, in 1939, 77 tons of pure molybdenum). Since the war, production has fluctuated a good deal, sinking to a minimum of 174 tons in 1950 and reaching a peak of 871 tons in 1953. In 1955 the output was 430 tons. Within these limits there have been rather wide fluctuations each year. Yugoslavia's molybdenum output would mean an essential addition to Soviet supplies.

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5. Supply Problems.

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[redacted]

In wartime or in a crisis certain problems are bound to arise. An estimate, shown in Table 4, has been made of production and consumption in the western world in wartime.

Table 4.

Estimated Consumption and Production in the Western World in Wartime.

(molybdenum content in tons)

	Production	Consumption	Deficit
North America	28.000	37.000	9.000
Europe	125	6.000	+ 5.875
			14.875
South America	1.675	0	÷ 1.675
Total	29.800	43.000	13.200

In wartime a production deficit of c. 13.000 tons would thus arise. This deficit may be met in two ways: 1. By consumption cuts. 2. By drawing on the strategic stocks.

ad 1. Consumption cuts could be made in two ways:

a. Partly by using less molybdenum in certain alloys. Some such retrenchments have already been made over the past few years without resulting in inferior products.

b. Partly by not using molybdenum steel for certain purposes. However, it is doubtful how practicable this way is, because it necessitates the use of other steel alloys which are just as scarce or even scarcer.

ad 2. Strategic stocks already exist [redacted] in some of the European consumer countries. The size of these stocks is not known with any certainty. It is to be expected that the strategic stocks [redacted] will increase by as much as the annual production surplus, which, in 1954, was 12.000 tons, almost the equivalent of one year's consumption deficit in wartime. In 1954 the

[redacted]

[redacted] industrial stocks of molybdenum concentrate amounted to 6.45o tons. In the case of Europe no accurate figures are available but it is thought that industrial stockpiles amount to c. 1ooo tons, the equivalent of 2 months' wartime consumption.

Theoretically molybdenum may be replaced by other metals, particularly tungsten and boron. The applications of boron are limited and in the event of a crisis the supply situation will be even more precarious than in the case of molybdenum.

The transport problems are not large because only small quantities are involved. On the other hand Europe's supply routes are long and vulnerable. The South American molybdenum concentrate goes to Europe. [redacted]

The future of molybdenum and its alloys lies in all the fields in which particularly heavy demands on strength and resistance to heat are made. Much research is aimed at the application of molybdenum in gasturbines, the jet engine and rockets.

Unfortunately molybdenum is easily oxidized. This tendency may, however, be reduced by alloying with other metals, especially titanium, niobium and vanadium.

In many applications in which molybdenum and its alloys function under high temperatures, oxidizing thus particularly easily taking place, a coating of various alloys such as aluminium-chromium-silicon or nickel-silicon-boron is used. These coatings assure a lifetime of at least between 98 and 5oo working hours at temperatures of 1ooo-11oo degs. centigrade. However, the problem has not yet been fully solved, several American laboratories are still at work on developing an effective method of protection for molybdenum parts. The moment a quite satisfactory solution is arrived at, molybdenum will find wide applications in motors.

5.2. The Problems of the Soviet Bloc.

It is generally assumed that molybdenum is among the most unmistakable strategic deficit commodities in the Soviet Bloc and that this metal, on account of its scarcity, causes great problems even in peacetime. Shimkin estimates the consumption of the Soviet steel industry to be between 25oo and 34oo tons of molybdenum annually. This estimate dates from 1951 and there is good reason to believe that the demand has increased since then.

Up to the time of the Second World War the USSR has practically no molybdenum production and was thus entirely dependent on import mainly from [redacted]

Table 5 shows molybdenum import and consumption in relation to steel production.

Table 5.

SU's import and consumption of molybdenum in relation to steel production.

Year	Molybdenum import (in tons)	Steel production (million tons)	Molybdenum consumption x) kilo/ton of steel	total (in tons)
1931	430	5.6	0.05	280
1933	405	6.9	0.05	345
1935	680	12.6	0.06	756
1937	1.832	17.7	0.08	1.436
1939	4.125	17.9	0.09	1.611
1941	1.076	15.0	a) 0.11	1.650
1942	2.776			
1943	1.868	9.7	a) 0.12	1.164
1944	1.828			
1945	1.480	11.2	a) 0.10	1.120
1947	...	13.3	b) 0.07	931
1950	...	24.8	c) 0.10	a) 2.480
1956	c. 1.100 tons from China	48.6	c) 0.06	3.850

x) = For Soviet molybdenum alloys, see appendix.

a) = The relative consumption increase is due either to more plentiful supplies or to armament production which requires harder steel alloys.

b) = The relative decrease to supply scarcity or disarmament.

c) = Estimate.

Until 1931 this import was on a very modest scale, but then increased considerably.

In the years 1931-1946 the USSR was the worlds' greatest importer of molybdenum. During this period the total import, as converted into molybdenum concentrate, 17.425 tons. The import reached a peak in 1939. In the postwar years the USSR has been able to obtain only slight quantities in western countries. Concurrently with the import increase between 1937 and 1946 the USSR increased its home production so much that it came to an amount of 600-700 per annum. In the war years, during 95 per cent. of molybdenum consumption was accounted for by steel alloys, the USSR has thus taken in molybdenum supplies, which may be considerably exceeded consumption.

This surplus has probably been used in building up new strategic stocks, which the molybdenum scarcity of the following years must have reduced a great deal.

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Considering the Soviet steel output in 1956 (48.6 mn. tons) and assuming a molybdenum consumption of o.o8 kilos per ton of steel a molybdenum consumption of 3.85o tons in the Soviet steel industry is arrived at. If the pattern of consumption in Russia is the same as [redacted] the 3.85o tons represent c. 9o per cent. of total consumption which will thus be c. 4.38o tons. To this comes perhaps a certain small consumption in the Satellite countries, which is also made up by the USSR. 50X1-HUM

On balance it is hardly too bold to assume that Soviet molybdenum production in together with the import from China (c. 1.1oo tons) is sufficient in peacetime to meet the country's soncumption and possible obligations provided the strictest economy is observed.

[redacted] the molybdenum supplies to the Soviet Bloc have become more plentiful since the war and that the situation is less critical than before. This is suggested also by Soviet offers of ferromolybdenum, small though they are, which have been made quite recently (1956/57, 5o tons). 50X1-HUM

The easing in the supply situation has also been brought about by the circumstance that the Soviet Bloc has to a certain extent been able to replace molybdenum with other alloying constituents, especially tungsten, the supplies of which are more plentiful.

In the event of war, when the relative as well as the absolute molybdenum consumption will rise, the present Soviet supplies would hardly be adequate. The country would then have to depend on strategic stockpiles and increased imports. Of primary importance will no doubt be the import from China and this import entails advantages as well as drawbacks. The advantages are mainly the strategically rather good location, the drawback first and foremost the immensely long and difficult transportation route.

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Appendix I

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Molybdenum Steel Types of the USSR.

In spite of heavy import and in spite of plans for the production of more types of molybdenum steel only two types were produced in the USSR by 1939:

1. 35 KhM YuA, a low chromium-molybdenum-aluminium degree steel type containing o,4-o,6 per cent. of molybdenum.
2. Kh 12M high chromium-molybdenum-vanadium degree steel type containing c,5-o,8 per cent. of molybdenum.

The first type is used in various machine parts. The second was used, subsequent to hardening, as a substitute for wolframite tool steel.((Only after the incorporation China aid the Soviet Bloc obtain any considerable wolframite reserves.)

During the war the production of other types of molybdenum steel was begun:

3. 4o Kh2 GM containing o,3-o,4 per cent. of molybdenum. For machine parts.

More significant, however, was the increased use during the war, of molybdenum in cast iron:

1. SCh 24-44 with o,2-o,6 per cent. of molybdenum. For airplane wheels and diesel engine valves.
2. SCh 28-48 with o,2-o,8 per cent. of molybdenum. Used, inter alia, for cylinder blocks.
3. SCh 32-52 with o,4-1 per cent. of molybdenum. Among other things, for gear wheel cogs.
4. SCh 35-56 with o,8-1 per cent. of molybdenum. Among other things, for gear wheel cogs.
5. SCh 38-6o.

Finally, since 1945, a type of high-speed tool steel containing wolframite, cobolt and molybdenum has been in regular production.

High-degree molybdenum tools and low-degree construction steel were not in regular production before 1947 although it was produced in certain cases.

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